memorandum

Environment and Resources
55 Wheeler Street, Cambridge, MA ◆ Tel: 617 492-7100 ◆ www.abtassociates.com

Abt Associates Inc.

Date	March 8, 2011
To	Ashley Allen, EPA
From	Emily Giovanni, Molly Cohen, and Elena Besedin, Abt Associates, Inc.
Subject	Urban Stormwater Impacts and River Size

EPA requested that Abt Associates conduct a literature review addressing the question of whether urban stormwater runoff impacts are mitigated by stream size (i.e. whether larger rivers are less impacted by urban stormwater runoff). We addressed this question using two methods:

- By determining whether the largest rivers in the United States are impacted by urban stormwater runoff using a total maximum daily load (TMDL) search, and
- By comparing available flow data (from the United States Geological Survey or other sources, described below) to documented cases of stream degradation caused by urban stormwater runoff.

This memo presents methods and results of this investigation. Our findings based on the two approaches suggest that urbanization affects all size streams in ways that are not easily predictable. Although the impacts of urbanization seem to be more clearly pronounced for the small and medium sized rivers compared with the largest rivers, we did not find conclusive evidence that the impacts of urbanization are limited to small streams only.

1 United States' Large Rivers

The United States Geologic Survey (USGS, 1990) identifies the 20 largest rivers in the United States according three different metrics – total length, area of watershed, and discharge rate at mouth – for a total of 32 rivers. We searched for TMDLs for these rivers to see whether any relevant impairments were at least partially attributed to urban stormwater. Of the 32 rivers identified by USGS (1990), we identified 8 that have a TMDL for at least one river segment that identifies urban stormwater as a source of impairment. We also did a search of other rivers with TMDLs that attribute impairment to stormwater, identifying an additional 5 cases of rivers[1] with stormwater causing impairments.

These 13 examples are summarized in Table 1. They each cite urban stormwater runoff as a contributor to water quality impairments. In general, it appears to be a somewhat larger concern or focus for those rivers not listed in USGS (1990), whereas for the 8 largest rivers (i.e. among those 32 identified by USGS), urban stormwater runoff was most commonly cited as one component in a larger portfolio of sources of degradation. These 13 examples demonstrate that large rivers can be affected by urban stormwater runoff,

[1]Not among the 32 largest rivers, but with lengths between 55 miles and 125 miles and with drainage areas between 311 mi^2 and 6,000 mi^2

in some cases to a significant extent (for example, see the Willamette River, Charles River, Los Angeles River, and Harpeth River cases).

2 Stream Degradation and Flow Data

We also collected papers documenting the impact of urban runoff on streams' biological and hydrologic quality, identifying flow data and the type and extent of impacts. The results of this review are summarized in Table 2. We drew these papers from earlier literature reviews focused on impacts of unregulated runoff flow to urban streams and channel morphology changes related to urbanization. Given that the selected papers include a fairly broad range of impacts and stream sizes, they may provide some indication of whether impacts vary depending on stream size.

To characterize the size of the affected streams included in the case studies, we used the cubic feet per second (cfs) metric, which is the most common flow unit. When it was available, we obtained flow data directly from the source document. When the source document did not include flow data, we used USGS gauge data to identify the gauge station nearest to the study area and to determine the annual average for the study year. For the multi-year channel morphology studies, we used the average annual flow rate value across the study years. When USGS stream gauge data were unavailable or the gauge was located on an area of the stream that did not seem representative of the study area, we performed additional internet searches to find stream flow data from other sources, including USGS and USFS surveys and websites of organizations involved in flood control and river protection.[2]

One of the reviewed studies (Pyron and Neumann 2008) directly addressed the correlation between river size and impact of urbanization. The study assessed the hydrologic regimes of streams in the Wabash watershed, and found that larger streams were more likely to have alterations (such as increased flows during storm pulses) due to urbanization than smaller streams. Beyond this example, we found no evidence that the impacts varied with the flow rate of the stream. In general, impacts varied widely, with variably-sized streams and rivers having significant impacts and others presenting only mild impacts. We note that because these papers used different methods to study a variety of impacts, making comparisons across studies is difficult. We did not conduct any additional analyses or statistical tests to establish whether a correlation exists.

[2] All sources of data are noted in Table 2.

Table 1: Impacts to Large and Medium Rivers from Urban Stormwater				
River	**Description**	**Status**	**Impacts from Urban Stormwater**	**Documentation**
Largest Rivers in the United States[1]				
Rio Grande, NM*	Flows 1,900 miles from Colorado into Mexico; watershed drains 336,000 mi^2	A middle portion (in central New Mexico) impaired for aluminum and bacteria	Runoff from urban areas and MS4s[2] cited as source of aluminum and bacteria contributing to impairment, although compliance with current general MS4 regulations was assumed to be sufficient to control both	NMED (2010)
Colorado River, TX*	Flows 862 miles; watershed drains 42,300 mi^2	A segment of the river below E.V. Spence Reservoir impaired for chloride and total dissolved solids	Three permitted MS4s are identified as point sources contributing to impairment, but are not considered major sources and none are required to reduced their loads to meet WLAs[3]	TCEQ (2007)
Snake River, ID*	Flows 1,040 miles; watershed drains 108,000 mi^2	Segments of the Hells Canyon portion (encompassing parts in Oregon and Idaho) impaired for dissolved oxygen, nutrients, sediment, mercury, pesticides, and temperature	Urban stormwater identified as a known source contributing to dissolved oxygen, nutrient, sediment, and mercury impairments; Municipalities had stormwater management programs and plans, and stormwater discharge permits included pollution prevention plans.	IDEQ (2004)
Columbia River, OR*	Flows 1,240 miles; watershed drains 258,000 mi^2	North Coast Sub-basin in Oregon, containing portions of Columbia River, impaired for temperature, bacteria, and dissolved oxygen	Although not quantified, urban stormwater is cited as a source of bacteria, and the management plan in the TMDL includes improvement of urban stormwater management	ODEQ (2003)
Willamette River, OR*	Flows 309 miles; watershed drains 11,400 mi^2	Main stem of river impaired for bacteria, mercury, and temperature	Urban stormwater runoff cited as primary contributor to bacteria impairment, in addition to other sources such as sewer overflows; urban stormwater runoff also being considered as a possible contributor to mercury impairment, but further research was underway; no immediate stormwater mitigation plans identified	ODEQ (2006)

Table 1: Impacts to Large and Medium Rivers from Urban Stormwater				
River	**Description**	**Status**	**Impacts from Urban Stormwater**	**Documentation**
Arkansas River, Kansas*	Flows 1,460 miles from Colorado into Kansas, Oklahoma, and Arkansas; watershed drains 161,000 mi^2	Portion in Kansas (upstream from Haven to junction with Salt Creek) impaired for nutrients	Stormwater not discussed as main contributor to impairment, but control of urban stormwater (specifically in Hutchinson) listed as important component of TMDL implementation	KDHE (2007)
Other Rivers				
Charles River, MA	Flows 79 miles from Echo Lake to Boston Harbor; watershed drains area 311 mi^2	Significantly impaired by algae and aquatic plants caused by excess nutrients, primarily phosphorus	Stormwater cited as primary contributor of excess nutrients (in addition to five municipal wastewater dischargers); Iterative approach to reducing nutrients recommended; for MS4s, includes construction and post-construction runoff control, illicit discharge elimination, pollution prevention and public involvement/education	Charles River Watershed Association and Numeric Environmental Services, Inc. (2009)
Los Angeles River, CA	Flows as an open channel for 55 miles from Canoga Park neighborhood of L.A. to Long Beach Harbor; watershed covers 834 mi^2	Impaired for nutrients and metals	Stormwater cited as primary contributor of metals during wet weather (other point sources are primary during dry weather); 40% of cadmium, 80% of copper, 95% of lead, and 90% of zinc; wastewater load allocations for stormwater discharge included in TMDL	LARWQCB (2007)
Spokane River, WA	Flows 112 miles from Lake Coeur d' Alene to Columbia River; watershed encompasses 6,000 mi^2	Impaired for dissolved oxygen and PCBs	Stormwater from urban areas (primarily the City of Spokane) cited as contributing to the River's dissolved oxygen impairment in addition to other point sources, although specific allocations were not ascertained; stormwater from urban areas accounts for a large proportion of PCB loadings; wastewater load allocations for MS4s; included in TMDL, as well as source control to limit phosphorous from MS4s	Washington Department of Ecology (2006); Washington Department of Ecology (2010)

Table 1: Impacts to Large and Medium Rivers from Urban Stormwater				
River	**Description**	**Status**	**Impacts from Urban Stormwater**	**Documentation**
San Gabriel River, CA	Flows 58 miles from San Gabriel Mountains through urbanized areas to Pacific Ocean; watershed covers 682 mi^2	Impaired for metals in various reaches	Urban stormwater runoff cited as primary contributor to impairment (via vehicle break pads and wear, building materials, pesticides, erosion of paint, etc); stormwater permitees encouraged to utilize BMPs and monitor effectiveness	U.S. EPA, Region 9 (2007)
Harpeth River, TN and its tributaries	Harpeth River flows for 125 miles and drains into Cumberland River; watershed includes 1,364 miles of streams and drains 863 mi^2	Impaired for sediment and habitat alteration	Wet weather sources of sediment are primarily attributed to urban stormwater (those regulated as MS4s and those not regulated as MS4s); intention to implement Storm Water Management Plan (SWMP), identify sources and implement mitigating BMPs.	Tetra Tech, Inc., et al. (2002)

1. as identified by USGS, 1990
2. MS4 = municipal separate storm sewer system
3. WLA = waste load allocation
4. TMDL = total maximum daily load
5. PCBs = polychlorinated biphenyls

* indicates that descriptive information was provided by USGS (1990), which identifies and characterizes the 20 largest rivers in the United States according to discharge, drainage area, and length.

Table 2: Urban Stormwater Impacts and Stream Size				
Rivers	**Location**	**Stream Size**	**Impacts from Urban Stormwater**	**Study / Size Data Source**
Saw Mill Creek	Middletown, CT	28.2 cfs[1]	Channel widening and enlargement, erosion, scouring, bank instability	Arnold et al, 1982
Rock Creek	Portland, OR	0-80 cfs	Increase in nutrients, dissolved oxygen and chemical oxygen demand	Boeder & Change, 2008
Raisin River	Ann Arbor, MI	822 cfs	Increase in nitrogen and phosphorus	Bosch, 2008
Huron River	Ann Arbor, MI	493 cfs		
Las Vegas Wash	Las Vegas, NV	150-200 cfs	Channel widening, incision; 12 - 48 m	Buckingham & Whitney, 2007 / LVWCC, undated
Lower St. Johns River	Jacksonville, FL	4,000-8,300 cfs	Greater organic matter breakdown	Chadwick et al, 2006 / Spechler, 2005
Kelsey Creek	Puget, WA	0-315 cfs	Hydrologic regime change and biological indicators	DeGasperi et al, 2009
Rock Creek	Portland, OR	192 cfs	Climate change increases total run-off by 1 - 5%, decreases summer run-off	Francyzk & Chang, 2009
Little Lehigh Creek	Lehigh Valley, PA	100.4 cfs (33-202 range)	Channel incision and general widening	Glaster et al 2006 / USGS gauge data (average 1947 – 1999, study period)
Anacostia River	Washington, DC	116-153 cfs	Polycyclic aromatic hydrocarbons contamination	Hwang & Foster 2008 / DC DOH, 2003
Unnamed	Fayettville, AR	153 cfs (33-280 range)	Channel depth increase, bank undercutting	Keen Zebert, 2007/ USGS Stream gauge data (average 1980-2010)
Watts Branch	Rockville, MD	Inner channel: 35-66 cfs; Bankfull channel: 192 - 395 cfs	Channel depth increase, sediment deposit increase; “marked alteration in stream behavior”	Leopold, 1972 / Shea, 2006
Burnt Mill Creek	NC	0 – intermittent flow	Urban stream had elevated fecal bacteria, biological oxygen demand, total suspended solids, organophosphate, surfactant	Mallin et al 2009 / NCDENR, 2004
Dead Run	Baltimore, MD	1,070 – 7,050 cfs	Hydrologic impacts	Nelson et al 2006

Table 2: Urban Stormwater Impacts and Stream Size

Rivers	Location	Stream Size	Impacts from Urban Stormwater	Study / Size Data Source
Wabash River (multiple sites)	Indiana	Flows taken from USGS gauge data	Larger streams more likely to have hydrologic alteration (increase flow during storm pulses) than smaller streams	Pyron & Neumann, 2008
Sacramento River	Sacramento, CA	~7,500 cfs[2]	Total organic carbon; about 17% attributable to urban sources	Sickman et al, 2007 / SAFCA, 2011
San Diego Creek	San Diego, CA	61 cfs	Channel erosion leads to increased sediment loads	Trimble 1997/ USGS gauge data

1. Cfs = cubic feet per second
2. The only flow data available for the Sacramento River was "Current River and Stream Condition," accessed March 3, 2011.

Sources

Arnold, C.L., P.J. Boison and P.C. Patton. 1982. Sawmill Brook: An Example of Rapid Geomorphic Change Related to Urbanization. *The Journal of Geology* 90(2):155-166.

Boeder, M. and H. Chang. Multi-Scale Analysis of Oxygen Demand Trends in an Urbanizing Oregon Watershed, USA. *Journal of Environmental Management* 87: 567-581.

Bosch, N. 2008. The influence of impoundments on riverine nutrient transport: An evaluation using the Soil and Water Assessment Tool. *Journal of Hydrology* 355: 131– 147.

Buckingham, S.E. and J.W. Whitney. 2007. GIS Methodology for Quantifying Channel Change in Las Vegas, Nevada. *Journal of the American Water Resources Association* 43(4):888-898.

Chadwick, M.A., D.R. Dobberfuhl, A.C. Benke, A.D. Huryn, K. Suberkropp, and J.E. Thiele. 2008. Urbanization Affects Stream Ecosystem Function by Altering Hydrology, Chemistry, and Biotic Richneses. *Ecological Applications* 16(5): 1796-1807.

Charles River Watershed Association and Numeric Environmental Services, Inc. 2009. Draft Total Maximum Daily Load for Nutrients in the Upper/Middle Charles River, Massachusetts. Control Number: CN 272.0. Prepared for Massachusetts Department of Environmental Protection and United States Environmental Protection Agency, New England Region.

DeGasperi, C.L., H.B. Berge, K.R. Whiting, J.J. Burkey, J.L. Cassin, and R.R. Fuerstenberg. 2009. Linking Hydrological Alteration to Biological Impairment in Urbanizing Streams of the Puget Lowland, Washington, USA. Journal of American Water Resources Association 45(2): 512-533.

District of Columbia Department of Health (DC DOH). 2003. District of Columbia Final Total Maximum Daily Load for Oil and Grease in Anacostia River. October 2003. Available electronically at: http://www.epa.gov/reg3wapd/tmdl/dc_tmdl/AnacostiaRiver/AnacoatiaOilReport.pdf

Franczyk, J and H. Chang. 2009. The effects of climate change and urbanization on the runoff of the Rock Creek basin in the Portland metropolitan area, Oregon, USA. *Hydrological Processes.* 23: 805-815.

Galster, J.C. and F.J. Pazzaglia, B.R. Hargreaves, D.P. Morris and S.C. Peters. 2006. Effects of urbanization on watershed hydrology: The scaling of discharge with drainage area. *Geological Society of America Bulletin* 34(9): 713-716.

Hwang, H.M and G.D. Foster. 2008. Polychlorinated biphenyls in stormwater runoff entering the tidal Anacostia River, Washington, DC, through small urban catchments and combined sewer outfalls. *Journal of Environmental Science and Health Part A.* 43: 567-575.

Idaho Department of Environmental Quality (IDEQ). 2004. Snake River -- Hells Canyon Total Maximum Daily Load.

Kansas Department of Health and Environment (KDHE). 2007. Arkansas River Basin Total Maximum Daily Load.

Keen-Zebert, A. 2007. Channel Response to Urbanization: Scull and Mud Creeks in Fayetteville, Arkansas. *Physical Geography* 28(3):249-260.

Las Vegas Wash Coordination Committee (LVWCC). Undated. Why is “the Wash” Important? Accessed 2 February 2011. <http://www.lvwash.org/html/important_wq_storm.html>

Leopold, L.B. 1973. River Channel Change with Time: An Example. *Geological Society of America Bulletin* 84:1845-1860.

Los Angeles Regional Water Quality Control Board (LARWQCB). 2007. Attachment A to Resolution No. R2007-014. Table 7-13.1: Los Angeles River and Tributaries Metals TMDL: Elements.

Mallin, M.A., V.L. Johnson and S.H. Ensign. 2009. Comparative impacts of stormwater runoff on water quality of an urban, a suburban, and a rural stream. *Environmental Monitoring and Assessment* 159:475-491.

Nelson, P.A., J.A. Smith and A.J. Miller. 2006. Evolution of channel morphology and hydrologic response in an urbanizing drainage basin 31: 1063-1079.

New Mexico Environment Department (NMED). 2010. US EPA-Approved Total Maximum Daily Load (TMDL) for the Middle Rio Grande Watershed.

North Carolina Department of Environment and Natural Resources (NCDENR). 2004. Assessment Report: Biological Impairment in the Burnt Mill Creek Watershed. Division of Water Quality, Planning Branch. February 2004. Available electronically at: http://portal.ncdenr.org/c/document_library/get_file?uuid=7659042f-f934-4730-af98-3b8a829da35c&groupId=38364

Oregon Department of Environmental Quality (ODEQ). 2006. Willamette Basin Total Maximum Daily Load (TMDL).

Oregon Department of Environmental Quality (ODEQ). 2003. North Coast Subbasins Total Maximum Daily Load (TMDL).

Pyron, M and K. Neumann. 2008. Hydrologic Alterations in the Wabash River Watershed, USA. *River Research and Applications* 24: 1175-1184.

Sacramento Area Flood Control Agency (SAFCA). 2011. “Current River and Streams Condition.” Accessed 3 March 2011. Available at: http://www.safca.org/floodRisk/riverConditions.asp

Shea, C.C. 2006. Upper Watts Branch Stream Restoration 30 Percent Design Report. Stream Habitat Assessment and Restoration Program. U.S. Fish and Wildlife Services. Chesapeake Bay Program Office. February 2006. Available electronically at: http://www.fws.gov/chesapeakebay/Stream%20Reports/Watts%20Branch%20Design%20Report/30Report.pdf

Sickman, J.O., M.J. Zanoli, and H.L. Mann. 2007. Effects of Urbanization on Organic Carbon Loads in the Sacramento River, California. Water Resources Research 43: 1-15.

Spechler, R.M. 2005. Estimated Discharge and Chemical- Constituent Loading from the Upper Floridan Aquifer to the Lower St. Johns River, Northeastern Florida, 1990-91. United Sates Geological Survey in conjunction with Army Corp of Engineers. Available electronically at: http://fl.water.usgs.gov/PDF_files/wri94_4132_spechler.pdf.

Tetra Tech, Inc., United States Environmental Protection Agency (U.S. EPA), and Tennessee Department of Environment and Conservation. 2002. Total Maximum Daily Load (TMDL) for Siltation and Habitat Alteration in the Harpeth River Watershed (HUC 05130204): Cheatham, Davidson, Dickson, Hickman, Rutherford, and Williamson County, Tennessee.

Texas Commission on Environmental Quality (TDEQ). 2007. Two Total Maximum Daily Loads for Chloride and Total Dissolved Solids in the Colorado River Below E.V. Spence Reservoir: For Segment Number 1426.

Trimble, S.W. 1997. Contribution of Stream Channel Erosion to Sediment Yield from an Urbanizing Watershed. *Science* 21(278): 1442-1444.

United States Environmental Protection Agency (U.S. EPA). 2007. Total Maximum Daily Loads for Metals and Selenium: San Gabriel River and Impaired Tributaries.

United States Geological Survey (USGS). 2011. USGS Real-Time Water Data for the Nation. Available electronically at: http://waterdata.usgs.gov/nwis/rt.

United States Geological Survey (USGS), Department of the Interior. 1990. Water Fact Sheet: Largest Rivers in the United States.

Washington Department of Ecology. 2010. Spokane River and Lake Spokane Dissolved Oxygen Total Maximum Daily Load: Water Quality Improvement Report. 07-10-073.

Washington Department of Ecology. 2006. Draft Spokane River PCBs Total Maximum Daily Load: Water Quality Improvement Report. 06-03-024.